"Integrated Probabilistic Analysis Environment (IPAE) for Proactive Failure-Resistant Design of NASA Aerospace Systems: A Pilot Study"

Presentation to NASA Headquarters Mission Directorate Chief Engineers

by Suren Singhal & the IPAE Team

April 1, 2008

(1:30 to 2:00 PM EDT)

NASA-Army Collaboration

Presentation Outline

- **What** are we doing? (3 charts)
- **How** are we doing it? (4 charts)
- What is the expected final **outcome**? (2 charts)
- **Summary** (1 chart)
- **Backup Charts**

What ? - IPAE Objective

Demonstrate probabilistic techniques for proactive failure-resistant design of aerospace systems

- Do a pilot study to develop broad Agency capability for NASA

- Leverage Army's IPAE for NASA applications

- Make a compelling case for use of IPAE for Design of ARES V & other Constellation systems

Make A Difference!

What ? - IPAE Scope

Advance the capability to develop, design, and operate NASA exploration, space operations, science, and aeronautic research systems using cutting edge tools capable of modeling uncertainties

An opportunity to show clear advantage of applications of Physics-based probabilistic analysis methods.

Example: Mass saving

Convert this Technical Excellence Opportunity into Future Capability!

What ? – The IPAE Team

NASA	Dan Dumbacher, Ralph Carruth, Suren Singhal, Pam Caruso, Herb Shivers, Jim Rogers, Randal Wallace (Army) & Team - MSFC
	Larry Green & Stephen Scotti – LaRC
	Tim Adams – KSC
	Prince Kalia – GSFC
	Curt Larsen & Ken Johnson - NESC
U.S. Army	**Bob Kuper, Steven Vaccaro & Team – Army,** Picatinny Arsenal
Academia	Erik VanMarcke, (Princeton University), Consultant
Industry	Paul Munafo - Teledyne Brown
	Terry Palmer - Davidson Technologies Inc.
	Bob Ryan, Jim Blair, Luke Schutzenhofer - Lee & Associates
Ad-hoc Advisors	• Bryan O'Connor, Chief of S&MA, NASA
	• Jaiwon Shin, AA - Aeronautics Research, NASA
	• BG William Phillips, Commander – Army, Picatinny Arsenal

The RIGHT Team!

How ? – IPAE Deliverables

Develop & Demonstrate IPAE for a NASA tool that cuts **across the range of NASA missions**

(1) Select & prioritize NASA tool

(2) Develop specification to integrate NASA tool into IPAE

(3) Integrate NASA tool into IPAE

(4) Conduct limited validation & verification

(5) Demonstrate NASA integrated IPAE tool

(6) Develop a plan for a broader NASA inquiry for use of probabilistic techniques

(7) Deliver IPAE for NASA tool, results of demonstration, and final report

Designed to capture the spirit of NASA TEI and deliver!!

How ? - Team Member Responsibility

- **NASA MSFC**
  - Lead center
  - Responsible for successful completion of the study & all deliverables within the proposed cost and schedule

- **NASA Centers**
  - Identify & select NASA applicable probabilistic model (s)
  - Provide model to Army for integration into IPAE
  - Evaluate the performance of IPAE with NASA model
  - Evaluate the results of IPAE for NASA example test case
  - Develop roadmap for broader inquiry
  - Support deliverables and briefings to NASA HQ

Team Members have a stake and are actively involved!!

How ? - Team Member Responsibility (continued)

- **Army & Partners**
  - Provide information & reports on Army IPAE
  - Provide specifications for, develop & deliver IPAE for NASA model
  - Perform V&V
  - Conduct analysis & provide results for NASA example test case
  - Support broader inquiry into probabilistic techniques
  - Support deliverables and briefings to NASA HQ
- **Academia** — Perform peer reviews
- **Industry**
  - Provide guidance & suggestions
  - Review deliverables and briefings
- **Ad-hoc Advisors**
  - Provide senior executive guidance & broad perspective

Expectation is 1 & 1 = 11

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Significant leveraging opportunities: $7-10M in Army investments

- Existing Integrated capabilities: $1.5M investment
  - Modules of the presently developed
- IPAE/ASIA Program investments: ~$2M thru ’09
  - Modules to be developed
- Composites Research – Reliability-based Design Optimization Capability tied to IPAE
  - FAST TRACK Phase 2 Program
  - Army investments: 70+50+750+350+300=$1.52M
  - NASA Investment leveraged by Army 400K
  - Total: $1.92M
- MEMS Research applications- $2.2M
  - Spin off research and applications programs: several $M

“Rapid Innovation” Tools, Methods & Best Practices and Processes

Outcome ? – Interim (3 months)

3/14	Partners attend kick off meeting
3/28	• **NASA briefs on technical aspects** • **Army briefs NASA team on IPAE** • **Project Leads (PL) develop format for list of models for Centers** • **NASA Centers begin developing list of candidate models**
4/31 to 5/15	**Prioritize candidates, coordinate with Army (Face-to-Face)**
5/22	PL deliver candidate to Army
5/31	**PL brief NASA HQ on accomplishments/candidate tool/ benefit/plan**

Must select the RIGHT tool!!!

Outcome ? – By End of TEI (12 months)

7/15	Army develops specs for integration of NASA model into IPAE
9/15	Army begins integrating NASA model into IPAE NASA Centers begin inquiry into broad Agency roadmap
11/15	Army reports on status of integration NASA, Army, Academia begin V&V of integrated product
1/15	Army/NASA/Team complete V&V of product
2/15	Army/NASA/Team deliver results for example test case
3/15	• **Army delivers integrated product & results to NASA** • **PL deliver integrated product & final report to NASA HQ**

Only the delivery of expected outcome will meet the expectation - It's Up to Us!!!!

Summary

- Probabilistic modeling of NASA systems is part of MSFC Engineering Vision
- This Pilot Study is a first step toward experiencing and realizing that vision

- NASA has high expectations for IPAE
- IPAE has visibility with Chief Engineers from all NASA Mission Directorates
- Army/Prof. Van Marcke, Consultant (Princeton) Collaboration is a Dream Team

- We are inspired and looking forward to making a difference

Let's shoot for the stars like NASA does!

Back Up Slides

- Deliverables & Schedule (2 slides)
- Plan for First Deliverable (3 slides)
- Army Leverage (slides)

IPAE Deliverables and Schedule

(1) Select & prioritize NASA application software for integration into the ARDEC IPAE (2 months) Will get ARDEC report ---- **NASA**/Team

(2) Develop outline specification to integrate NASA supplied software into IPAE based on NASA requirements (4 months). Will get ARDEC report ---- **ARDEC/**NASA/Team

(3) Integrate NASA software into IPAE (7 months) ---- **ARDEC**/Team

(4) Conduct limited validation and verification of software build resulting from integration of NASA software and the IPAE (9 months) ---- **ARDEC**/NASA/Team

IPAE Deliverables and Schedule (Continued)

(5) Demonstrate NASA integrated IPAE software for an example test case provided by NASA NLT TBD (10 months) ---- **ARDEC**/NASA/Team

(6) Develop a plan for a broader NASA inquiry into the use of other probabilistic techniques including IPAE via a joint assessment by the 10 NASA Centers (11 months). Will get ARDEC report ---- **NASA**/ARDEC/Team

(7) Deliver IPAE for NASA selected software, results of the example test case, and final report (12 months) ---- **ARDEC**/NASA/Team

Criteria to Select NASA Software for Integration into IPAE

- Used for many applications at NASA e.g. structural/thermal analysis FE based? For metals/Composites?

- High visibility at HQ, Cuts across all 4 NASA Mission Directorates

- Not too complex, runs reasonably fast, Right for integration into IPAE

- Must be able to make available to Army/Contractor for say 1 year

- Being used for ARES I, High potential to use for ARES V

- Potential to show high pay off e.g. weight saving, reliability enhancement

Actions for 1st Deliverable

Communicate Deliverable details to all Team Members – March 28 Videocon

- **Firm up tool selection criteria – April 7 – Pam/Suren**

- **Solicit list of tools/applications in a specified format (develop excel table based on tool selection criteria) from team (include all ten NASA Centers as much as possible) – March 28 Videocon, April 7 & ask for first list by April 30 – Suren/Randy (Ken from NESC, Jim/Jeff from MSFC, Terry from industry, Larry from LaRC, etc. – Randy/Terry to persuade). Think who else to ask &ask – Paul McConnaughey, Patrick Hull, ---(Randy/Terry)**
- **Randy/Terry/Ken/Jim/Jeff to prioritize list & present to Suren/Pam on May 5**
- **Suren/Pam/et. al to agree on priority & to email & then discuss with team – May 7 & ask for team feedback by May 16**
- **Suren/Pam to present list to Dan/Ralph/Paul/etc. for advice on May 19 & follow-up for Ad-hoc Advisors feedback between May 19 to May 23.**
- **Suren/Pam/Team select top 2 tools/application & communicate to Army on May 26**

PLAN FOR FIRST DELIVERABLE

NASA Centers identify candidate projects for probabilistic analyses

Project Leads develop format for candidate projects, for example:

- Title: Inter-stage Structural Design
- Traditional Solution: NASTRAN
- Probabilistic Solution: xyz method
- Benefits: Meets all requirements & saves mass

NASA
Technical Excellence Initiative
2008

Probabilistic Technology Partnership Technical Videocon
28 Mar 08

TECHNOLOGY DRIVEN. WARFIGHTER FOCUSED.

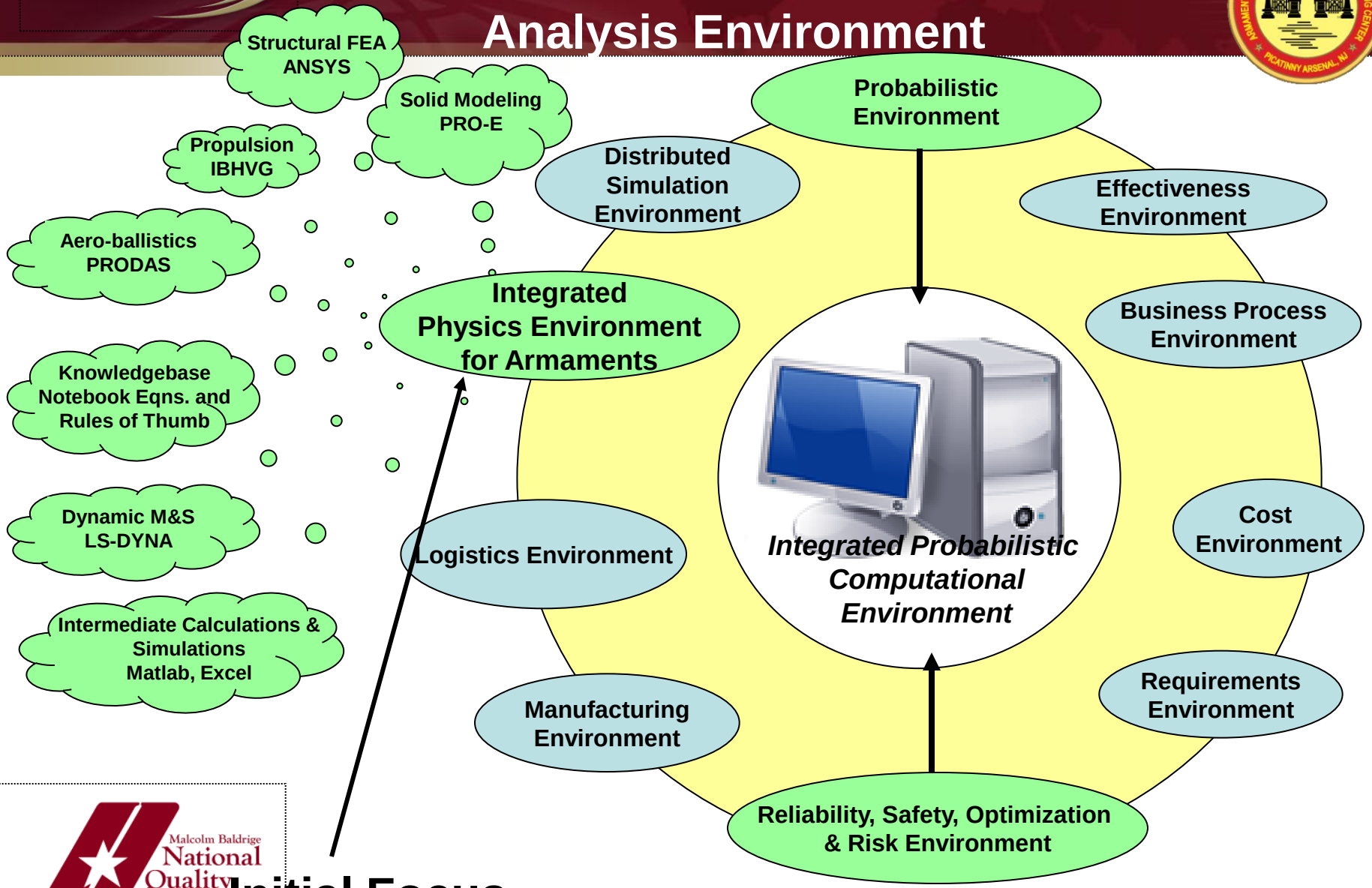
Robert J. Kuper

Dean, Reliability Engineering Competency

PM, Reliability for the Future Force

PM, Advanced Seamless M&S Integration Architecture

Integrated Probabilistic Analysis Environment



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Initial Focus

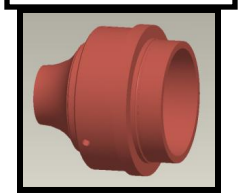
"Physics Environment"

Use Case – Developing a Round

Selected Concept

User Reqts.

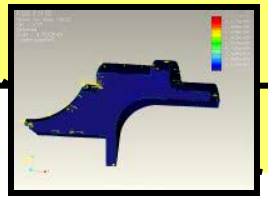
CAD DESIGN (ProE)

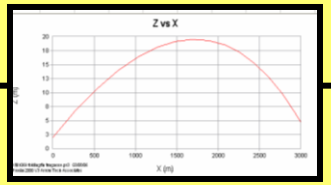


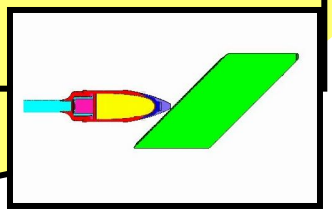
Overarching Probabilistic Model UNIPASS

PHYSICS BASED MODELS

Interior Ballistics	***Exterior Ballistics***	***Terminal Ballistics***
-Structural (ANSYS or ABAQUS) -Propulsion (IBHVG2)	- Aerodynamics (TRAJ or PRODAS) Output – Phit	(CTH) Output - Pkill

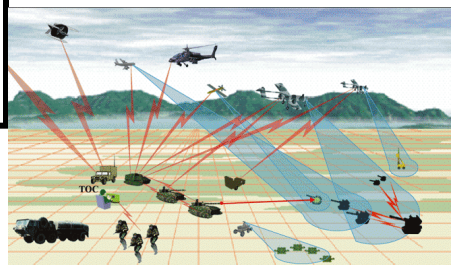






Probabilistic Input

COMBAT MODELS CASTFOREM, G-Wars



LOGISTICS Models

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TECHNOLOGY DRIVEN. WARFIGHTER FOCUSED.

Modeling and Simulation in LOS MP Design Process

Decrease design time and # of tests

Initial conceptualization to meet requirements and overall program

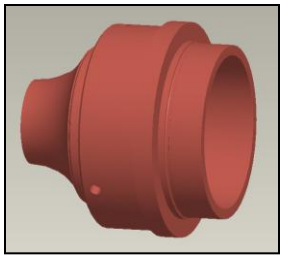
Definition of design musts and system limits

Definition of high risk process and long lead items

Define shortfalls of M&S and fill gaps with test

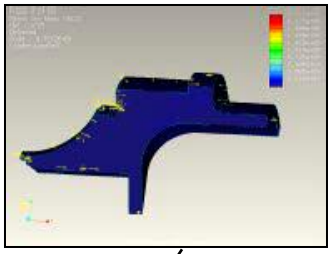
Total Savings:
From warhead modeling alone:
$3.45 Mil and 28 months

Pro Engineer Solid Modeling in PDM workspace

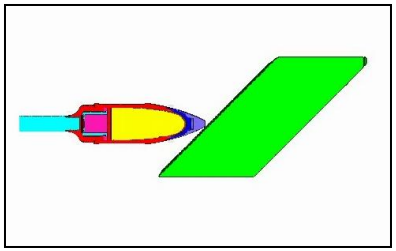


In bore loads and muzzle velocity from IB simulations in IBHVG2

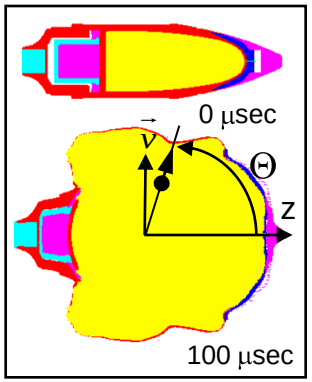
Math based stress analysis FBD/ ANSYS/ Pro Mechanica



Target penetration modeled in CTH



Fragmentation in CALE/PAFRAG



Failure in any model reiterates design

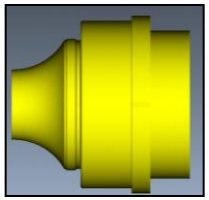
War Games/Lethality Models

Antipersonnel: CASRED/MEM

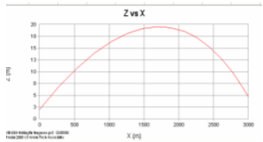
Anti Armor: AJEM/MUVES-S2

Flight Performance

Verify models thru test



Flight performance modeled in PRODAS



Part Manufacture using 3D numerical control creation

X-ray after DR concrete wall

Fragmentation Testing

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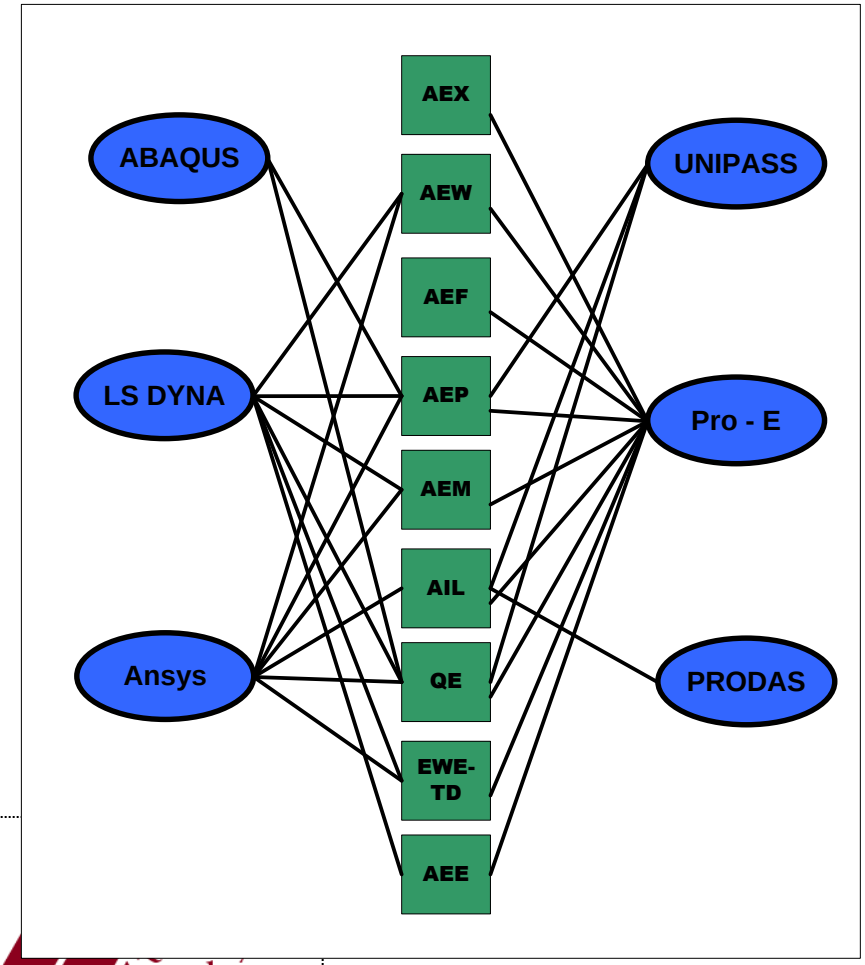
TECHNOLOGY DRIVEN. WARFIGHTER FOCUSED.

IPAE Details

- M&S Integration Architecture will provide:
  - Total Seamlessly Integrated “End to End” Life Cycle solution
  - Significant M&S performance enhancements
  - Significant efficiencies (reduce/eliminate non-value-added labor)
  - Improved M&S in support of the ARDEC Product Development Processes
  - Better, Cheaper, Faster Transition to Soldier Products
  - Quality, cost, manufacturing and effectiveness environments to evaluate products before development life cycle
- Probabilistic Technology
  - Integrates Physics and Probability Theory to gain benefits of both
  - Better decisions from Quantified impact of uncertainty and sensitivity- A MAJOR GAP in our Life Cycle Processes
  - Significant Leap-Ahead Technology enhancement for Integrated LC Decision-making in our Product Development & Support processes thru Modeling & Simulation

Organizational Modeling Dependence



- Integration of models in order to pull together the domain specific knowledge of various organizations
- Demonstrates importance of interoperability of M&S components for "***better, cheaper, faster***" development and integration